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(54) **Epoxy powder coating composition for use in electrostatic coating.**

(57) A powder coating composition is disclosed which includes a particulate material containing an epoxy resin and a curing agent, and fine powder of a charge controlling agent such as an acrylic resin, silica or a mixture thereof. The charge controlling agent is deposited on surfaces of the particles of the particulate material.

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This invention relates to a powder coating composition suitable for use in electrostatic coating.

Electrostatic coating is now used in various fields because of a lot of advantages thereof such as easiness in controlling the thickness of coatings and absence of a step of preheating articles to be coated. Thus, a number of powder coating compositions are commercially available for use in electrostatic coating processes. Known powder coating compositions, however, has a problem because it is difficult to obtain thick coatings having a smooth surface. Namely, when a coating having a thickness of 250 μm or more is to be formed, particles of the coating composition cause electrostatic repelling so that the surface of the resulting coating becomes non-uniform.

The present invention has been made with the foregoing problem in conventional powder coating compositions in view. In accordance with one aspect of the present invention there is provided a powder coating composition comprising a particulate material consisting of particles having a particle size in the range of 3-180 μm and a volume resistivity of at least 10^7 ohm-cm and each containing an epoxy resin and a curing agent for the epoxy resin, and a charge controlling agent selected from the group consisting of an acrylic resin having an average particle size in the range of 0.05-1 μm and silica whose primary particles having an average particle size in the range of 2-500 nm, the amount of said charge controlling agent being 0.01-5 % based on the total weight of said particulate material and said charge controlling agent, and said charge controlling agent being present on surfaces of said particles of said particulate material.

In another aspect, the present invention provides a powder coating composition comprising:

a first particulate material consisting of first particles having a particle size in the range of 3-180 μm and a volume resistivity of at least 10^7 ohm-cm and each containing a first epoxy resin and a first curing agent for the first epoxy resin;

a second particulate material consisting of second particles having a particle size in the range of 3-180 μm and a volume resistivity of at least 10^7 ohm-cm and each containing a second epoxy resin and a second curing agent for the second epoxy resin;

a first, particulate, charge controlling agent depositing on surfaces of said first particulate material; and

a second, particulate, charge controlling agent depositing on surfaces of said second particulate material, said first and second charge controlling agent differing in static characteristics.

The present invention will now be described in detail below.

First Embodiment:

The powder coating composition of the first embodiment according to the present invention is composed of a particulate material consisting of particles having a particle size in the range of 3-180 μm and a volume resistivity of at least 10^7 ohm-cm. Each of the particles contains an epoxy resin and a curing agent for the epoxy resin.

Any conventionally used epoxy resin may be used in the present invention. Examples of suitable epoxy resins include glycidyl ethers of bisphenol A, bisphenol S, bisphenol F, phenol novolak resins and cresol novolak resins; glycidyl ester epoxy resins; glycidyl amino epoxy resins; cycloaliphatic epoxy resins; linear aliphatic epoxy resins; heterocyclic epoxy resins; and halogenated epoxy resins. These epoxy resins may be used singly or as a mixture of two or more. Epoxy resins which are solid at 20° C are generally used. But, it is possible to use the solid epoxy resins in conjunction with liquid epoxy resins as long as the mixed epoxy resins are solid at 20° C.

Conventional curing agents may be used for the above epoxy resins. Illustrative of suitable curing agents are aromatic amines, acid anhydrides, guanidine compounds such as dicyandiamide, and imidazole compounds.

In addition to the epoxy resin and the curing agent, the particulate material may further contain a filler, a pigment or the like conventional additive.

The particulate material is blended, in a dry state using, for example, a Henschel mixer or a Nauta mixer, with a charge controlling agent selected from an acrylic resin having an average particle size in the range of 0.05-1 μm , preferably 0.15-0.6 μm and silica whose primary particles having an average particle size in the range of 2-500 nm, preferably 5-100 nm so that the charge control agent deposits on the surface of the particles of the particulate material. The amount of the charge controlling agent is 0.01-5 % based on the total weight of the particulate material and the charge controlling agent.

The acrylic resin to be used as the charge controlling agent is a homopolymer or a copolymer of an alkyl ester of acrylic or methacrylic acid. Polymethyl methacrylates and polymethyl acrylates are examples of suitable acrylic resins.

When frictionally contacted with iron powder, acrylic resins are either positively or negatively charged. Both of the positively and negatively chargeable acrylic resins may be used for the purpose of the present invention.

In this case, it is preferred that the negatively chargeable acrylic resins or a mixture of the negatively chargeable and positively chargeable acrylic resins be used in combination with the particulate material which is good in chargeability. In the case of the particulate material which is relatively poor in chargeability, then it is preferred that the particulate material be used in combination with the positively chargeable acrylic resins or a mixture of the positively chargeable and positively chargeable acrylic resins. The mixing ratio of the positively chargeable acrylic resin to the negatively chargeable acrylic resin is selected so as to obtain optimum results according to the chargeability of the particulate material.

The ratings of "good" and "poor" in the chargeability of the particulate material are determined by as follows: Sample particulate material is discharged through a nozzle of an electrostatic coating gun (Model AH-1 manufactured by Nordson Inc.) with an air pressure for discharging the particulate material of 1.5 kg/cm² and an air pressure for accelerating the particulate material of 3.5 kg/cm² while measuring the charge by means of a charge meter equipped in the coating gun. When the measured charge is 0.6 mA or more, the particulate material is rated as being good in chargeability. When the measured charge is less than 0.6 mA, then the particulate material is rated as being poor in chargeability.

The amount of the acrylic resin to be blended with the particulate material is preferably 0.1-1 % by weight based on the total weight of the acrylic resin and the particulate material.

Silica to be used as the charge controlling agent may be surface-treated or non-treated silica. Surface treatment of silica is performed so as to modify the silanol groups thereof with a trimethylsilyl group, aminosilyl group or the like group.

When silica is dispersed in water to form a slurry containing 5 % by weight of the silica, the slurry shows various pH values according to the type thereof. The silica whose such slurry shows a pH of less than 7 is referred to as being "acidic" while the silica providing a pH of 7 or more is referred to as being "alkaline" in the present specification. Generally, non-treated silica is acidic because of the presence of silanol groups, while surface-treated silica is alkaline because the silanol groups have been modified.

It is preferred that alkaline silica or a mixture of alkaline silica and acidic silica be used in combination with the particulate material which is good in chargeability. In the case of the particulate material which is relatively poor in chargeability, then it is preferred that the particulate material be used in combination with acidic silica or a mixture of alkaline and acidic silica. The mixing ratio of the alkaline silica to the acidic silica is selected so as to obtain optimum results according to the chargeability of the particulate material.

The amount of the silica to be blended with the particulate material is preferably 0.01-1 % by weight, more preferably 0.05-0.1 % by weight based on the total weight of the silica and the particulate material.

Second Embodiment

In the second embodiment according to the present invention, two, different, first and second charge controlling agents are used and are separately deposited on different particles of particulate material.

The particulate material described with reference to the above first embodiment may be used in the second embodiment. The particulate material on which the first charge controlling agent is to be deposited may be the same as or different from that on which the second charge controlling agent is to be deposited.

The charge controlling agent is fine powder (with a particle size of 1 μ m or less) of an organic or inorganic substance which is inert to the curing reaction of the epoxy resin and which has a polar group so that it can change the static characteristics of the particulate material when deposited on the particulate material. Illustrative of charge controlling agents are organic polymers containing oxygen, nitrogen, sulfur or the like polar elements, inorganic oxides and metal salts. Especially suitable is the use of the acrylic resin or silica described with reference to the first embodiment.

The two, first and second charge controlling agents to be used in the present invention should differ in static characteristics from each other. The difference in chargeability results from various surface properties of the particles of the charge controlling agents, such as surface acidity and polarity. Such a difference in static characteristics may be created by, for example, surface treating suitable organic or inorganic powder in two different manners. The surface treatment may be, for example, a heat treatment, a radiation treatment, a treatment with an acid or an alkali, a chemical modification treatment and an adsorption treatment. More specifically, by treating a powder with an organic acid and by separately treating similar powder with an organic base, there are obtained two charge controlling agents with different static characteristics (surface acidity). In this case, non-treated powder may be substituted for one of the acidic and alkaline charge controlling agents.

It is preferable to use a combination of first and second charge controlling agents showing pH of 7 or more and less than 7, respectively, when dispersed in water in an amount of 5 % by weight. Such first and second charge controlling agents are suitably formed of silica having unmodified silanol groups and treated silica having modified silanol groups, respectively. It is also preferable to use a combination of first and second charge con-

trolling agents which are positively and negatively charged, respectively, upon contact with iron powder. Such first and second charge controlling agents are formed of acrylic resins. Thus, those charge controlling agents described above with reference to the first embodiment are suitably used in the second embodiment.

The coating composition according to the second embodiment may be obtained as follows. First, two particulate materials A₁ and B₁, which may be the same or different and each of which contains an epoxy resin and a curing agent are provided. Two particulate, charge controlling agents A₂ and B₂ are then dry mixed with the particulate materials A₁ and B₁, respectively, to deposit the charge controlling agents A₂ and B₂ on the particulate materials A₁ and B₁, respectively, thereby to obtain two kinds of mixtures A₃ and B₃. The two mixtures A₃ and B₃ are blended with each other to obtain the powder coating composition of the present invention. The blending ratio A₃:B₃ is suitably 1:9 to 9:1, more preferably 3:7 to 7:3. The total amount of A₂ and B₂ is generally in the range of 0.01-10 %, preferably 0.1-5 % based on the total weight of A₁, B₁, A₂ and B₂.

The following examples will further illustrate the present invention.

Example 1

Powder coating compositions were prepared by dry blending the ingredients shown in Table 1 in proportions (% by weight) shown in Table 1. The ingredients used are as follows:

Particulate material:

EPIFOAM F-221 (manufactured by Somar Corporation)

Epoxy resin: diglycidyl ether of bisphenol A

Curing agent: dicyandiamide

Particle size: 80 mesh or finer

Volume resistivity: 5×10^{16} ohm-cm

Charge: 0.7 mA (good chargeability)

EPIFOAM F-220 (manufactured by Somar Corporation)

Epoxy resin: diglycidyl ether of bisphenol A

Curing agent: imidazole

Particle size: 80 mesh or finer

Volume resistivity: 3×10^{16} ohm-cm

Charge: 0.4 mA (poor chargeability)

Charge controlling agent:

Silica, CARPLEX FPS-3 (manufactured by Shionogi Inc.)

pH of 5 % Slurry: 7.5

Average particle size: about 15 nm (primary particles)

Silica, CARPLEX # 1120 (manufactured by Shionogi Inc.)

pH of 5 % Slurry: 10.7

Average particle size: about 15 nm (primary particles)

Silica, AEROSIL #300 (manufactured by Nihon Aerosil Inc.)

pH of 5 % Slurry: 4

Average particle size: about 7 nm (primary particles)

Non-treated

Polymethyl methacrylate, MP-2701 (manufactured by Soken Kagaku K. K.) ,

Chargeability: positively charged upon contact with iron

Particle size: 0.35-0.5 μ m

Mw: 4×10^4 - 10×10^4

Polymethyl methacrylate, MP-1000 (manufactured by Soken Kagaku K. K.)

Chargeability: negatively charged upon contact with iron

Particle size: 0.35-0.5 μ m

Mw: 25×10^4 - 50×10^4

The thus prepared coating compositions were tested for their performance in electrostatic coating. The tests are performed as follows:

A motor armature having 10 slots each having a length of 40 mm, a diameter of 29 mm and a width of 2 mm is coated with a test sample coating composition using an electrostatic fluidized bed coating apparatus for 30 seconds at a voltage of 50 kV with a fluidizing air atmosphere of 0.2 kg/cm². The amount of the coating

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composition applied is measured. The condition of the slots is observed to determine whether or not the coating composition is got sufficiently into the the slots to th depth thereof.

The results are summarized in Table 1.

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Table 1

Experiment No.	1	2	3	4	5	6	7	8	9	10	11*	12*
Particulate Material												
EPIFOAM F-221	99.9	99.9	99.9			99.8	99.7	99.7			100	
EPIFOAM F-220				99.9	99.9				99.7	99.7		100
Silica												
CARPLEX FPS-3	0.1											
CARPLEX #1120		0.1	0.05		0.05							
AEROSIL #300			0.05	0.1	0.05							
Acrylic Resin												
MP-2701							0.3	0.2	0.3	0.1		
MP-1000						0.2		0.1		0.2		
Amount of Coating (g)	3.3	4.0	3.2	3.1	3.1	3.3	3.0	3.2	4.3	3.9	2.5	2.5
Condition of Coating in Slots	good	good	good	good	good	good	good	good	good	good	poor	poor

*: Comparative Sample

Example 2

The ingredients shown in Table 2 in proportions (% by weight) shown in Table 2 were blended to obtain mixtures A and B. Coating compositions were prepared by mixing the mixtures A and B with each other. The ingredients used are as follows:

Particulate material:

EPIFOAM F-221 (the same as used in Example 1)

Charge controlling agent:

Silica, CARPLEX # 1120 (the same as used in Example 1)

Silica, AEROSIL #300 (the same as used in Example 1)

Polymethyl methacrylate, MP-2701 (the same as used in Example 1)

Polymethyl methacrylate, MP-1000 (the same as used in Example 1)

Table 2

Experiment No.	13	14	15
Mixture A			
Particulate Material			
F-221	49.85	49.95	49.8
Charge Controlling agent			
Acrylic resin MP-2701	0.15		0.2
Silica #1120		0.05	
Mixture B			
Particulate Material			
F-221	49.85	49.95	49.9
Charge Controlling agent			
Acrylic resin MP-1000	0.15		0.1
Silica #300		0.05	
Amount of Coating (g)	4.3	4.1	4.9
Condition of Coating in Slots	good	good	good

Example 3

Experiments Nos. 11 and 15 were repeated in the same manner as described except that the coating time was changed to 60, 90, 120 and 150 seconds. The amount of the coating composition deposited to the armature was as shown in Table 3.

Table 3

Coating Time (seconds)	30	60	90	120	150
Amount of Coating (g)					
Experiment No. 15	4.9	7.0	7.8	8.8	9.9
Experiment No. 11*	2.5	3.4	3.8	4.0	4.1

*: Comparative Sample

Claims

1. A powder coating composition comprising a particulate material consisting of particles having a particle size in the range of 3-180 μm and a volume resistivity of at least 10^7 ohm cm and each containing an epoxy resin and a curing agent for the epoxy resin, and a charge controlling agent selected from the group consisting of an acrylic resin having an average particle size in the range of 0.05-1 μm and silica whose primary particles having an average particle size in the range of 2-500 nm, the amount of said charge controlling agent being 0.01-5 % based on the total weight of said particulate material and said charge controlling agent, and said charge controlling agent being present on surfaces of said particles of said particulate material.
2. A powder coating composition comprising:
 - a first particulate material consisting of first particles having a particle size in the range of 3-180 μm and a volume resistivity of at least 10^7 ohm-cm and each containing a first epoxy resin and a first curing agent for the first epoxy resin;
 - a second particulate material consisting of second particles having a particle size in the range of 3-180 μm and a volume resistivity of at least 10^7 ohm-cm and each containing a second epoxy resin and a second curing agent for the second epoxy resin;
 - a first, particulate, charge controlling agent depositing on surfaces of said first particulate material;
 - and
 - a second, particulate, charge controlling agent depositing on surfaces of said second particulate material, said first and second charge controlling agent differing in static characteristics from each other.
3. A composition according to claim 2, wherein the weight ratio of a total of said first particulate material and said first charge controlling agent to a total of said second particulate material and said second charge controlling agent is in the range of 1:9 to 9:1.
4. A composition according to claim 2, wherein the total amount of said first and second controlling agents is in the range of 0.01-10 % based on the total weight of said first and second particulate materials and said first and second charge controlling agents.
5. A composition according to claim 2, wherein said first particulate material is the same as said second particulate material.
6. A composition according to claim 2, wherein said first and second charge controlling agents show pH of 7 or more and less than 7, respectively, when dispersed in water in an amount of 5 % by weight.
7. A composition according to claim 6, wherein said first and second charge controlling agents are formed of silica having unmodified silanol groups and treated silica having modified silanol groups, respectively.
8. A composition according to claim 2, wherein said first and second charge controlling agents are positively and negatively charged, respectively, upon frictional contact with iron powder.

9. A composition according to claim 8, wherein said first and second charge controlling agents are formed of acrylic resins.

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